R & D facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Turbines

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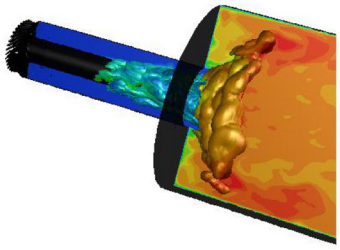
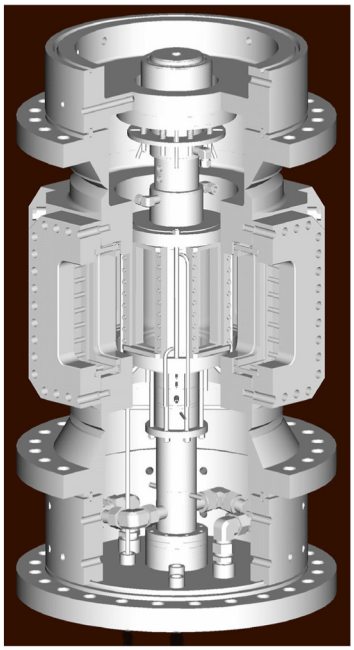
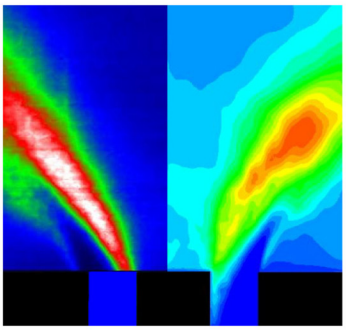
# NETL Simulation Validation Studies (SimVal) Project







*OH (Flame) Image*
*SimVal Experiment CFD Simulation*

The U.S. Department of Energy (DOE) Turbines Program established a stringent nitrous oxide ($NO_x$) emission goal for future turbine power generation of 2 ppmv (at 15 percent $O_2$) with a turbine inlet temperature of 2600 °F. These future turbine power plants are expected to operate on either hydrogen-rich fuels, such as coal-derived synthesis gas (syngas), or pure hydrogen derived from shifting the syngas. Achieving these goals will require improved combustor designs and concepts that may be dramatically different than those currently utilized.

Significant and costly experimental testing is usually required to assess and verify the performance of new combustor designs. Ideally, new concepts could be evaluated with Computational Fluid Dynamic (CFD) simulations to reduce development time and cost. However, current simulation capabilities cannot reliably predict the effects of fuel variations on flame extinction, emissions levels, and dynamic stability. Furthermore, very little data with controlled boundary conditions are available to validate CFD predictions at actual turbine engine conditions or to assess combustor performance without ambiguous or assumed boundary conditions.

The National Energy Technology Laboratory (NETL) Simulation Validation Studies (SimVal) combustor (see image at right) is an optically-accessible, intermediate-scale (3 MW thermal) combustor that provides combustion data sets to promote

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CFD code development at realistic gas turbine conditions and contribute to improved fundamental understanding of turbulent combustion processes. Fuel composition, operating pressure, inlet air temperature, and combustor geometry are varied to study the effects of these parameters on flashback and lean extinction limits, dynamic stability, and pollutant emissions. The combustor is operated over a wide range of elevated pressures, inlet air temperatures, and flow rates, to provide data at realistic gas turbine conditions. The effects of fuel composition are studied by adding controlled quantities of hydrogen to the baseline natural gas fuel. The modular combustor design enables the combustor to be reconfigured to study geometric effects, such as fuel injector and swirl vane design and position.

Experiments in the SimVal combustor are conducted with precise control of thermal, acoustic, and flow boundary conditions. Well-defined boundary conditions are central to providing useful validation data sets by allowing the performance of CFD codes to be predicted with greater fidelity. This is accomplished in SimVal by measuring heat losses and liner temperature profiles, isolating the combustor acoustically, controlling the flow field at the combustor inlet and outlet, and controlling fuel-air mixing at the combustor inlet. The combustor features full optical access to the combustion region, which uniquely allows direct observation and detailed imaging of the flow field in the flame region and flame structure at all operating conditions. Comparison of experimentally observed and measured flow fields and flame structures with those predicted by CFD simulations (see image at left) is an important measure of the accuracy of the simulations.

Unique in DOE, the SimVal combustor in NETLs High-Pressure Combustion Facility provides the capability to directly observe high-pressure combustion processes at realistic gas turbine conditions with precisely controlled boundary conditions. The facility is therefore uniquely suited to provide combustion data that will improve the fundamental understanding of key processes in turbulent combustion and may promote the development of novel, ultra-low emission, fuel flexible combustors for the DOE Turbines Program.